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DESCRIPTION OF TYPICAL MINE-TELEPHONE SYSTEMS AND SUGGESTIONS FOR MAKING IMPROVED INSTALLATIONS

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C. L. BROWN

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DESCRIPTION OF TYPICAL MINE-TELEPHONE SYSTEMS AND SUGGESTIONS FOR MAKING IMPROVED INSTALLATIONS[1]

By C. L. Brown[2]

INTRODUCTION

The heavy loss of life from mine fires in some coal mines recently has focused attention on the importance of maintaining reliable communication systems between the active working sections of mines and the surface. A study of conditions following disasters in mines indicates that in several instances lives could have been saved if telephone communication had been available. Communication systems were not installed in some of these mines where disasters occurred, and in other mines they were installed in such a manner as to be rendered useless following a mine explosion or fire. Lives have been lost because of the inability of the rescue crews or persons directing the rescue to communicate with trapped men. Cases are known where many lives might have been saved had it been possible to give instructions for escaping or for location of barricades.

More than 500 major disasters in which 5 or more lives have been lost have occurred in mines in the United States. The total number of lives lost in these disasters has exceeded 13,000. Some of the victims died instantly; but for many it was hours and in some instances days before death occurred. Evidence found in recovery operations following some of the disasters indicates that many died needlessly because of the lack of suitable means of communication between the underground working areas and the surface.

A localized gas and dust explosion in a coal mine in 1930 resulted in the death of 82 men; 2 were killed outright by the force of the explosion, 6 by a combination of burns and afterdamp, and 74 by afterdamp. About 140 men escaped or were rescued following the explosion. Of these, 119 escaped with little or no assistance, 2 were rescued promptly following the explosion, and 19 were rescued from behind a barricade. Seven bodies were recovered from behind an ineffective barricade in another place; subsequent investigation proved that these men might have been guided to a safe location had an effective communication system been available.

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7385."
[2] Mining-electrical engineer, Bureau of Mines, Pittsburgh, Pa.

An explosion in a coal mine in 1940 resulted in the death of 63 men; 8 were killed by burns and afterdamp, and 55 were killed by afterdamp. Few, if any, of the men were killed outright by burns and afterdamp. Eighteen men escaped without assistance from the immediate explosion area, and 12 others working on the same split of air escaped unaided. Forty-one bodies were found behind a barricade that had been ineffectively erected and located. Evidence in the form of a note found on one of the victims indicated that some of them were alive several hours after the explosion. A suitable system was not available to permit communication with persons who were unable to escape; therefore, persons directing the rescue work had no knowledge of the number of men who had survived the explosion.

A fire in a coal mine in 1944 resulted in the loss of 66 lives. One hundred ninety men were in the mine when the fire started; 66 were trapped i by the fire, and 124 escaped unassisted. Sixty of the 66 men killed had barricaded themselves in 1 area; 1 man had attempted to barricade himself alone in another area; and 5 men had apparently attempted to escape around the fire. Persons who directed the attempted rescue of the men who were trapped were in general agreement that a suitable means of communication would have aided in a possible saving of many lives.

In each of these disasters, and in many others, the lack of a suitable means of communication between trapped men and persons on the surface resulted in the loss of many lives that might have been saved had such facilities been available.

This circular describes some existing communication systems underground points out desirable and undesirable features in the systems, and discusses methods of installation whereby the communication systems are less likely to be rendered inoperative following mine fires and explosions.

The telephone systems in four coal mines in western Pennsylvania are described; the mines are designated as A, B, C, and D. The systems represent two types of underground circuits, systems using a central ringing device, and a system that is uncommon in coal mines.

MINE A

General Information

Mine A, developed in the Pittsburgh coal bed, has a daily production of approximately 4,000 tons and is classed gassy by the Pennsylvania Department of Mines. The average number of employees underground is 485. The voltage on the underground trolley system is 550.

The telephone system consists of 35 bridging-type telephones equipped with magneto ringing devices, approximately 50,000 feet of 2-wire circuits, and 2 switchboards. The underground system extends to the surface through 4 shafts, the deepest of which is 198 feet. All telephones are installed in intake air.

Telephones

Desk-type telephones are installed in the dispatcher's office, underground shop, and offices on the surface. Other telephones underground are nonpermissible mine-type in metal cases. A few of the telephones are of permissible type but are not maintained in permissible condition. The telephones, which are installed in break-throughs or in recesses in the coal ribs, are usually placed on boards fastened to 2- by 12-inch wooden planks secured to the ribs by expansion bolts.

The ringing devices consist of 45-BG 5-bar magnetos and 2,500-ohm ringers. Two No. 6 dry-cell batteries are used in each telephone. Many of the telephones have been in service for a considerable period of time and have been rebuilt in the company shops. The factory wiring has been replaced with wiring that has either rubber or synthetic insulating materials. The telephones are given a company number, and a record is kept of the date they were rebuilt. Heat is not used to prevent accumulation of moisture in the telephones.

Telephone-Circuit Conductors

The telephone cable conductors are No. 14 copper wires. Some of the cables are insulated with rubber and nonabsorbing rubber-compound jackets, and some have rubber insulation with jackets of treated fibrous material. Both types are designed for burial in the floor and for resisting moisture. It has been necessary to install some of the latter-type cables because of the restrictions on rubber; however, cables having rubber-compound jackets are generally preferred for use on or under the floor. All the cables are installed on the clearance side of entries; and where trolley-wire crossings are made, they are installed under the track. The cable in the vicinity of the man-shaft bottom is buried in the floor, but is laid on the floor close to the rib on the main haulageway entries and supported by nails or cleats on timbers in the side entries. Those extending to the surface in the four shafts are supported by suitable clamps at the top and so placed as to present a minimum exposure to damage. The circuit is not installed near high-voltage lines at any point, and the exposure to lightning on the surface is limited to approximately 200 feet of circuit.

Ten-circuit switchboards in the dispatcher's office and in the repair shop permit the system to be sectionalized into six circuits or connected as a single system. The switchboards are approximately 2,000 feet apart and are connected by a cable that contains five 2-wire circuits. The switchboards are plugged during off-shift periods so that calls can be made throughout the mine without the aid of a switchboard operator. Approximately 1,500 feet of three-circuit cable is installed inby the repair shop, but only one 2-wire circuit is in use; the other two circuits are maintained for future use.

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Cable Taps and Splices

Branch circuit taps are generally laid on the floor, but splices are kept off the floor by attaching the splice to a board on the rib 2 feet or more above the floor. The conductor ends are fastened together by means of clamp-type connectors and are covered with rubber tape. This connection permits tests of the circuits to be made readily. Permanent splices are ma by the use of splicing sleeves "swaged" or pressed on the conductors. The spliced joints are insulated with rubber tape and covered with a weather-proofing tape.

Telephone-Circuit Protection

The telephone circuits are equipped with lightning arresters and fuses at the bottom of each shaft where the circuits extend to the surface. Switches are also installed at these locations to permit the circuits to be disconnected. Lightning arresters and fuses are installed in the lines at the top of the man shaft and at the entrances to buildings on the surface for protection against lightning. The protection provided for this purpose is considered adequate.

Maintenance of Telephone System

The telephones and circuits are maintained in good operating condition by qualified persons who have no other specific duties.

The main causes of faults in the cables on the floor are damage by too of haulageway-maintenance workers and from supplies thrown out of cars onto the cable. Roof falls sometimes cause damage to cables that are suspended, as well as to cables on the floor; buried cables are not subjected to damag from any of these causes. The telephone-maintenance personnel at the mine prefers that the cable be installed on the floor or overhead to expedite the location of faults in the cable.

Summary

The following are considered desirable features of the system:

1. Low cost of circuit installation.
2. Low maintenance cost.
3. More than one connection is made between the surface and undergrou
4. The circuits are reasonably dependable for normal operation.
5. Faults can be located readily.
6. The exposure to high-voltage circuits is negligible.
7. Protection against lightning is provided on or near the surface.

The following are considered disadvantages of the telephone system, particularly in case of a disaster:

1. The telephones and circuits are likely to be made inoperative by an explosion or fire in the area in which they are installed.

2. The exposed parts of the circuit are subjected to mechanical damage during normal operation of the mine, although the possibilities are less than with overhead construction where bare conductors are used.

MINE B

General Information

Mine B, in the Upper Freeport coal bed, has a daily production of approximately 1,200 tons of coal and is classed gassy by the Pennsylvania Department of Mines. The average number of employees underground is 180. Direct-current power on the trolley system underground is 275 volts.

The underground telephone system that serves the working section of the mine consists of a public-utility telephone circuit which enters the mine through an intake air shaft 253 feet deep, a telephone near the shaft bottom, and two extension telephones on the haulageway. One extension telephone is approximately 2,000 feet from the telephone at the shaft bottom, and the other is approximately 1,000 feet in the opposite direction. In addition, communication is provided between the surface and the bottom of the 190-foot coal-hoisting shaft by a 2-wire circuit and 2 telephones equipped with magneto ringers. The telephones are installed in intake air.

Telephones

Desk-type dial telephones installed in booths are used in the public-utility system, and bridging-type telephones with magneto ringers are used in the coal-hoisting-shaft system. The public-utility telephone system was installed approximately 7 years ago, using one telephone underground. The extensions were made about 2 years later.

The application of heat to the telephones in this mine has not been necessary to prevent accumulations of moisture because of the dryness of the locations where they are installed.

Telephone-Circuit Conductors

The public-utility telephone circuit on the surface extends from a trunk cable to the air shaft, a distance of approximately 300 feet. The cables that extend into the mine from the surface have rubber jackets and are installed in conduit. Extensions are No. 12 conductors, rubber-insulated and with metallic-tape armor, laid on the clearance side of the haulageway floor. The circuits underground are not exposed to high voltage. The metallic-armored cable is spliced by twisting the conductors together, insulating them with rubber tape, and covering each splice with weatherproof tape. The armor is maintained continuous across each splice but is not connected to permanent grounds.

Telephone-Circuit Protection

Approximately 300 feet of the public-utility telephone circuit on the surface is exposed to lightning, and a lightning arrester and fuses are installed in the circuit at the top of the air shaft. A ground connection is made from the arrester to a plate buried in the ground nearby.

The local telephone circuit in the hoisting shaft is not exposed to lightning nor to high-potential power circuits; therefore, protective devices are not considered necessary.

Maintenance of Telephone Systems

The public-utility telephone system inby the top of the air shaft and the local system in the hoisting shaft are maintained by the coal company.

Falls of roof are the chief causes of faults in the extension-telephone circuits, but the construction of the cable is such that these faults can be observed readily by visual inspection.

The connection to the public-utility telephone circuit has been satisfactory from the standpoint of service, permitting communication with distant points on the surface, but is inadequate in the number and location of the telephones underground. Relatively little maintenance has been necessary on the telephones or the circuit.

Summary

The following are considered desirable features of the public-utility telephone system:

1. It is possible to communicate with distant points on the surface from the telephone stations underground.

2. Less maintenance is required with the type of telephones provided than with the common battery types generally used in mines.

3. The cable installed in the telephone circuit underground is thought to be more serviceable than the conductors generally used for this purpose.

4. The exposure to high-voltage circuits is negligible.

5. Protection against lightning is provided for the cable near the entrance to the mine.

Considering the system from the standpoint of continuity of service following a mine fire or explosion in the area in which the telephones and circuits are installed, the following are disadvantages:

1. The telephones are not protected from explosions and fires.

2. Only one connection is provided between the surface and underground on the main communication system.

MINE C

General Information

Mine C, developed in the Pittsbourgh coal bed, has a daily production of approximately 4,000 tons of coal and is classed gassy by the Pennsylvania Department of Mines. The number of employees underground averages approximately 800. The voltage on the underground trolley system is 550.

The telephone system consists of 70 bridging-type telephones equipped with magneto ringing devices, approximately 17 miles of 2-wire circuit, and a 6-circuit switchboard at the dispatcher's station. The dispatcher's station, several thousand feet underground, will be moved near the bottom of the man-hoisting shaft soon. The underground system is connected to circuits on the surface at 4 places. All telephones are in intake air.

Telephones

Desk-type telephones are installed in the offices on the surface and underground, and nonpermissible mine-type telephones are installed at other locations throughout the mine. The ringing devices consist of 45-BG 5-bar magnetos and 2,500-ohm ringers. The installations are made in a manner to minimize damage from falls of roof. Telephones in damp locations are installed in steel booths, and two 275-volt lamps connected in series and attached to the 550-volt trolley circuit prevent the accumulation of moisture in the telephones. The lamps are connected to the power source through 2-conductor rubber-covered cable. The metal-cased telephones installed along the haulageways are supported by means of expansion bolts in holes drilled in the ribs, and the cases are grounded to the mine track as a protection against shock. It was reported that no difficulty is experienced from the procedure of grounding the telephone cases.

Telephone-Circuit Conductors

The telephone circuits leading into the mine are multiple-conductor rubber-covered cables, and single-conductor No. 9 galvanized-iron wires with weatherproof insulation are used on the main circuits underground. Branch lines from the main circuits to telephones are 2-conductor rubber-covered cables. The main-circuit conductors are spaced about 8 inches apart and supported overhead on insulators on the clearance side. At points where trolley-wire crossings are necessary, additional protection is provided by covering the wires with rubber hose and by guarding the top and sides of the trolley wire with wooden boards.

A switchboard at the dispatcher's station permits the system to be sectionalized into six circuits or connected as a single network.

Conductor Splices

Splices are made in the conductors of the main circuits by means of splicing sleeves or by securely twisting in a manner similar to a Western Union splice. Connections to the main circuit for branches are made by the use of clamp-type connectors. Connections and splices are covered with friction tape.

Telephone-Circuit Protection

The amount of telephone circuit exposed to lightning on the surface is kept at a minimum; but, where there is exposure, lightning arresters are installed on the lines where they enter the mine and buildings.

Maintenance of Telephone System

The telephones and circuits are maintained by persons who have been assigned these specific duties. Falls of roof are the main causes of faults in the circuits, and moisture and dust are common causes for failure of telephones. The service obtained from this system has been satisfactory for normal operation of the mine.

Summary

This method of constructing the telephone circuits has the following advantages over buried conductors:

1. Faults in the circuits can generally be located by visual inspection.

2. The circuit conductors are not exposed to high voltage, except at points where it is necessary to cross the trolley-wire circuit. Protection against contact between conductors and the trolley wire is provided by the use of additional insulation on the telephone conductors and guard boards on the trolley wire.

3. The cost of the circuit conductors compares favorably with the cost of other conductors.

4. Connections between the surface and underground are maintained at more than one point.

5. The necessary protection against lightning is provided for circuits on the surface.

The undesirable features of the system and telephone installations are as follows:

1. The telephones and circuits would probably be inoperative following a serious explosion or mine fire.

2. The telephone circuits are subjected to breakage from falls of roof during normal operation of the mine.

MINE D

General Information

Mine D, in the Lower Kittanning coal bed, has a daily production of approximately 3,500 tons of coal, and is classed gassy. The average number of employees underground is 617. The underground trolley system is energized with 275 volts.

The telephone system consists of 50 bridging-type telephones equipped with magneto ringing devices, approximately 70,000 feet of 2-wire circuit, and a 10-circuit switchboard equipped with a ringing device operated on a 110-volt alternating-current power circuit. Three connections are made from the underground system to the surface. All telephones are installed in intake air.

Telephones

The telephones installed underground are mine-type, except for four which have wooden cases; all are nonpermissible. The telephones are installed in underground offices, in recessed places in the rib, or in places where there is a minimum exposure to damage during normal operation of the mine. The telephones are supported securely by means of suitable expansion bolts. The ringing devices in the telephones consist of five-bar magnetos and 1,600- or 2,500-ohm ringers. A 50-watt 300-volt lamp placed in a metal box is attached to the bottom of each telephone to prevent accumulation of moisture. The lamps are installed in porcelain sockets similar to those used in electric signs, and the wires are covered with loom where they enter the boxes. The telephone cases are not grounded for protection against shock.

Telephone-Circuit Conductors

The major part of the telephone circuit is a twisted pair of conductors, and the remainder comprises two single conductors. The conductors are supported on insulators placed on the rib or overhead on the clearance side of the entries. Part of the two-single-conductor circuit is bare wire, and the remainder is insulated. The twisted-pair circuits are installed on split knobs, and rubber hose is used on the conductors where they cross the trolley wire.

The system is sectionalized into nine circuits, which terminate on a 10-circuit switchboard in the underground dispatcher's office. The switchboard is equipped with an electric-power-operated ringing device and a hand operated magneto. The latter device is maintained for use in case of a failure of the power operated ringer. The switchboard connections are not arranged so that the entire system can be connected as a single network but plugs are available for connecting any three of the nine circuits. Thi arrangement is considered satisfactory for normal operation.

Circuit Taps and Splices

Branch circuit taps and splices are made by clamping or securely twisting the conductors together, and the joints are covered with insulating materials where the conductors are insulated.

Telephone-Circuit Protection

The telephone circuits are equipped with lightning arresters and fuses near the points where they enter the mine, at each telephone, and on each circuit at the underground switchboard.

Maintenance of Telephone Systems

The telephones and circuits are maintained by qualified persons. The main causes of faults in the twisted-pair circuits are from moisture and mechanical damage. Fall of roof is the most common cause of faults in the two-wire single-conductor circuits. The telephone system is well-maintaine and the service appears to be adequate for normal underground requirements.

Summary

The following are considered desirable features of this telephone system:

1. The unusual feature of this system is the central ringing device operated from an alternating-current power source.

2. Adequate lightning protection is provided on the surface and underground.

3. Multiple connections to the surface are provided.

The following are considered undesirable features:

1. The system would probably be rendered inoperative by a fire or an explosion.

2. The circuit conductors are subjected to damage from falls of roof during normal operation of the mine.

3. The circuit is exposed to high voltage circuits.

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DISCUSSION OF ADVANTAGES AND DISADVANTAGES OF TYPICAL SYSTEMS

From the summaries of advantages and disadvantages of the four telephone systems described, it is found that none has been installed in a manner that might be free of destruction if a serious mine fire or explosion effected the areas in which they are installed. Three of the systems have more than one connection between the surface and underground. One system has no exposure to high-voltage circuits, and two are guarded against contact with high-voltage circuits by means of additional insulation at the points where crossings are made. In the first system, exposure to high voltage is avoided by installation of the telephone circuits in the floor where crossings are necessary. Electric lamps are used in the telephones in one installation without grounding the telephone cases.

The normal function of underground communication systems is to conduct the business of mining operations; however, it is not uncommon for the system of communication to be a possible means of saving lives and property. With this latter thought in mind, some desirable features of a system of communication may be summarized as follows:

1. Basically, the system should be well-designed, with consideration given to future requirements as the mine is developed.

2. The materials used should be (within economic limits) of the best obtainable for the particular system.

3. Connections from the underground system to the surface should be made at as many points as practicable. Preferably, some connections should be made near active working sections through boreholes, shafts, or other openings.

4. The telephones and circuits should be installed so as to minimize, insofar as feasible, the possibility of being destroyed or rendered useless in case of a mine fire or explosion.

5. The telephone circuits should be isolated from power conductors to prevent them from becoming energized with dangerous potentials and to reduce interference in the telephone system.

6. Telephone circuits on the surface that are exposed to lightning and are connected with underground circuits should be protected by suitable lightning arresters.

7. Enough accessible junction boxes should be installed to permit faults to be located readily.

DETAILS OF METHODS AND MATERIALS FOR INSTALLATION OF IMPROVED UNDERGROUND TELEPHONE SYSTEM

Methods of Installation

The wide variation in physical conditions and methods of mining preven uniform standards for telephone installations that are applicable to all coal mines. Recognizing this fact, the descriptions given herein are intended to apply to conditions as found in many coal mines.

Underground telephones and connecting circuits that are installed in the usual manner cannot withstand high temperatures and violence that ordinarily result from mine fires and explosions. The reliability of an underground system under such conditions depends entirely upon the degree of protection provided against damage. These facts should be considered when permanent systems are designed. Unfortunately, the choice of methods for making installations that are dependable under all conditions is limited, and the use of sound engineering principles and the best materials obtainable will not result in infallible systems; however, it is possible to produce a system that is far superior to the average installation now in use by guarding against conditions that are likely to cause failure from an explosion or fire. An installation designed to withstand these adverse conditions is expected to function at high efficiency and require a minimum of attention under normal operation.

Telephone-circuit conductors are the most vulnerable part of a system, and it is difficult to provide adequate protection under all conditions. None of the methods employed where the circuit conductors are installed on the mine floor, supported along the ribs, or supported overhead can be considered reliable under adverse conditions. The most practicable method known that will provide a reasonable amount of protection is to bury the telephone circuits in the mine floor. It is impracticable to eliminate all underground circuits in the average mine, but the length of the main conductors usually can be reduced by making multiple connections between the surface and underground circuits through shafts, drill holes, or other openings. Telephone systems can be made inoperative, or their efficiency seriously impaired, by short circuits resulting from falls of roof, mine fires, explosions, or other causes. An entire system or a part of a system may be short-circuited by the destruction of a telephone or the burning of a cable. Therefore, the performance of any system under all conditions is determined largely by the amount of attention given to the details of protection against failures from all probable causes. Telephones installed in the usual manner along haulageways are not adequately protected against destruction from mine fires and explosions. Those placed in recessed pockets in solid coal are afforded some protection against explosions, but protection against fire is lacking. Installations made in fire-resistant rooms with circuit connections made in the floor or through drill holes from the surface are less likely to be damaged than those made in the usual way. The cost of building fire-resistant rooms may be further justified by their use for other purposes, such as mine offices and first-aid stations. If properly equipped, they may also be used for barricading under certain conditions.

Nonpermissible telephones cannot be used safely in an atmosphere that is suspected of containing or being likely to contain an explosive mixture of air and gas, and their use in connection with recovery operations in gassy mines is limited to areas in which ventilation has been restored. Therefore, telephones installed underground should by all means be permissible and maintained in a permissible condition so as to be of maximum use following a disaster.

It is considered good practice to drill holes between the surface and the active working sections of the mine for the installation of electric circuits. Holes may be drilled especially for this purpose, or they may be holes that are drilled before development for testing coal beds and retained for use later in connection with the communication system. Holes that have been used for communication and abandoned may, in some instances, be utilized for other purposes, such as for power cables or pumping water to the surface, thereby reducing the cost chargeable to the communication system.

The efficiency of the bridged-type-telephone system is greatly reduced when the number of telephones connected permanently to the circuit exceeds a certain number. The number of telephones that can be connected permanently to a circuit depends upon the type of equipment in the telephones and the resistance of the circuits. For this reason, it is necessary to divide large systems into a number of circuits by means of a switchboard for satisfactory operation of a considerable number of telephones.

Telephone circuits on the surface that are installed above ground and not suitably shielded from lightning require some form of protective devices to prevent possible fire and shock hazards in buildings and mines.

Specifications of Materials and Details of Installations

Telephone Circuit Conductors

The selection of conductor sizes for telephone systems in mines is based on factors governing mechanical strength. Nos. 14 and 16 AWG are common conductor sizes selected for single-circuit cables; the conductor size is usually smaller in multiple-circuit cables. Where it is necessary to divide a telephone system into a number of circuits, as is the case in large mines, multiple-circuit cables are usually selected, and it is considered good practice to install cables that have spare circuits for future use. The requirements as to the number of conductors in cable are determined by the lay-out of the system and the future as well as the immediate needs.

Telephone cables for general use underground and in drill holes may be jacketed with nonabsorbing rubber compounds or other materials that are suitable for excluding moisture. Lead-armored cables have not proved satisfactory for burial in the floor of many mines because of chemical and electrolytic action on the lead.

Cable Installation

Cables may be supported in shafts and drill holes by several methods; the construction of the cable, weight, and length are factors that determin the most suitable type of support. In all telephone-cable installations, the type of support selected should be such that the total unsupported weight of any section of the cable will not exceed that which will permit a reasonable factor of safety (ratio of breaking strength of cable to stress). Safety factors of 5 to 7 are usually allowed, depending upon the type of cable. The important requirements for supporting cables by the conductors are that the support be strong mechanically and of a design that will permit uniform weight loading of the conductors, insulation, and jacketing materials. Cables that have two No. 14 or 16 copper conductors and are jacketed with nonabsorbing rubber compound can be supported by the conducto in installations where the depth does not exceed approximately 300 feet. Cables of this type can be installed where the depth exceeds 300 feet by th use of supports at intermediate points, for example, by attachment to timbers, walls of shafts, or to steel messenger wire. The tensile strength of messenger wire used for this purpose should be at least two times the maximum full loading tension. Cables constructed with steel-wire armor are suitable for installations in shafts and drill holes and can be used where the depth exceeds 300 feet. Cables of this type are constructed so that th total weight of the cable is supported by the steel armor at the top of the shaft or drill hole. A safety factor of 5 is usually permitted on steel-wire armored conductors. Cables in shafts should be adequately protected against damage by falling or moving objects; and, similarly, protection should be provided at the top of shafts and drill holes by placing the cabl in conduit or in the ground. Installations in large-diameter holes used fo ventilation should be armored or in conduit. It is desirable that telephon cables suspended vertically in shafts or drill holes be continuous without splices. Particular attention should be given to the matter of locating th telephone circuits away from power wires and providing adequate protection where crossings with power circuits are necessary.

The cost of trenching the mine floor varies widely and depends upon the hardness of materials and the methods and tools employed. Track-mounte coal-cutting machines have been used successfully for this operation in medium-hard- and soft-bottom materials. Similar equipment mounted on rubbe tires may be used in trackless areas. The cost of trenching is high where the hardness of the bottom materials is such that blasting is necessary. After a suitable trench at least 12 inches deep has been prepared, cable installations are made by laying the cable in the bottom of the trench and filling the trench with incombustible materials. The materials used for filling the trench should be such that the cables can be removed readily without damage if it is found necessary to remove them.

Cable splices made underground should be in boxes suitable for buryin in the mine floor, unless the splices are in fire-resistant rooms. Splice boxes installed in the mine floor should be constructed with covers and packing glands that will exclude moisture and be of a material that will resist chemical action of mine water. To provide protection for the splice

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boxes equal to that required for cables, they should be buried in the floor to the same depth as the cables, and their exact locations should be indicated by permanent markings. The number of splice boxes required depends upon several variable factors, such as the length of cables when purchased, the distance between telephones, and location of branches. Preferably, the number of splices should be kept to a minimun, but enough points should be established to permit fault tests to be made readily.

Fire-Resistant Rooms

Fire-resistant rooms should be constructed in a solid block of coal to be most effective; however, where it is necessary that they be constructed in break-throughs that have been driven through between entries, the break-throughs should be closed with strong stoppings and the telephones installed in pockets recessed in solid coal. Steel doors equipped with weights that will make them self-closing should be installed at the entrances to the rooms. Rooms that are used exclusively for telephones need not be larger than 6-1/2 by 4 by 4 feet, but if other uses are made of them they may be constructed larger in accordance with the requirements.

Telephones

Telephones installed underground in gassy mines should be permissible, otherwise, the safety with which the system could be used following an explosion would be questionable. Nonpermissible telephones cannot be used safely in a gassy mine after an explosion until ventilation has been restored. Therefore, to provide an effective communication system that can be used immediately following an explosion, telephones suitable for use under such conditions must be installed and maintained in good condition at all times.

Batteryless-type telephones suitable for use on large systems have not been developed; however, there are telephones of this type that may be used satisfactorily in connection with emergency communication systems - for example, between an underground telephone station and the surface through shafts or drill holes. The simplicity of construction, safety, and dependability of the batteryless telephone make it readily applicable to emergency or stand-by systems.

Drill Holes

Drill holes to be used in connection with communication systems may be 3-1/2 inches in diameter, or larger, depending upon the type of drill employed and whether the hole is used for other purposes. Preferably, all holes should be cased throughout for the purpose of excluding water and to prevent the possibility of damage to cables by caving. Large-diameter holes that are drilled into fire-resistant rooms should be capped on the surface to reduce the possibility of damage to doors from forces that may be created by explosions; likewise, small-diameter holes should be capped or otherwise protected to prevent objects from being thrown or placed in them promiscuously.

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Switchboards

The selection of suitable switchboards for underground service does not present a severe problem, since the installations are usually made in dry, well-heated rooms. However, manually operated switchboards cannot be used underground where extensive systems are designed and installed with the idea that they may be useful in connection with recovery work or to persons trapped in a mine. Automatic or manually operated switchboards may be installed on the surface to perform the required switching operations. Systems that have manually operated switchboards underground may not be of maximum use in case of a disaster.

Protection Against Lightning

Telephone systems that are exposed to lightning should be protected by means of suitable lightning arresters installed at each point where the circuits enter buildings and mines. The effectiveness of lightning arresters depends upon a satisfactory ground connection; therefore, each arrester should be connected to a ground of known resistance. Preferably, the resistance should be less than 5 ohms, as determined by means of a suitable ground-testing instrument.

Fault Location in Telephone Cables

Faults in telephone-cable conductors of uniform cross section and resistance can be located readily by means of suitable instruments available for this purpose. These instruments can be used successfully for fault location only on circuits that are maintained with this purpose in mind. Circuits that are repaired by replacing conductors with conductors of unequal resistance, poor insulation, and high-resistance splices are not adaptable to fault location by means of instruments that depend upon circuit resistance of a known value for their operation.

Much can be done to make possible the use of instruments for locating faults in mine-telephone circuits by improved maintenance methods. The first requirement is that good materials must be installed correctly; second, all repairs must be made in accordance with good engineering practices, particularly as to conductor replacements and the making of splices.

The difficulty in locating faults is the chief objection made by operating men to the installation of cables in the mine floor.

CONCLUSIONS

A study of available data on mine disasters in the United States during the past century reveals startling facts regarding the number of fatalities that have resulted from mine fires and explosions. In many of the large explosions, only a few of the total men killed have been killed outright. The largest loss of life has resulted from deadly gases that follow explosions and mine fires. Many of these fatalities may be attributed indirectly to lack of proper training of workers and to the lack of adequate communication systems in mines.

It is generally recognized that, if the necessary precautions are not taken, coal-mine fires may be a great potential hazard and may jeopardize the lives of many men, not only those who may be cut off from escape but also those engaged in fighting the fire. The definite fire hazards in virtually all coal mines should be considered at each mine, and every feasible precaution should be taken to prevent fires and explosions. The frequent occurrence of major coal-mine fires and explosions during the past century indicates a lack of effective precautions to prevent such disasters though the frequency and severity of such disasters have been greatly reduced in recent years.

The methods suggested for making installations of telephone systems should if placed in effect, eliminate some of the inherent weaknesses of telephone systems now installed in mines. The principles involved are not new and have been thoroughly proved on other applications. The apparent excessive cost of making installations as outlined is fully justified by the possible saving of lives and property, and the higher operating efficiency resulting from dependable communication systems.